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AUTHOR McLeod, Douglas B.; Adams, Verna M.
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ABSTRACT

Preservice elementary teachers enrolled in a mathematics course were randomly assigned to one of two treatment groups for instruction on computation in bases other than 10. Group 1 (Min-M) involved minimal guidance and a concrete level of abstraction, while group 2 (Max-S) had a large amount of guidance and dealt with concepts at a symbolic level. Subjects in both groups were given pretests, posttests, and a measure of field independence (hidden figures). Results were analyzed using multiple regression techniques and supported the hypothesis that field-independent students would learn more in the Min-M group, while field-dependent students would learn more if assigned to the Max-S treatment. (SD)

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Relating Field Independence and a Discovery Approach to Learning Mathematics: A Trait-treatment Interaction Study*

Douglas B. McLeod and Verna M. Adams

San Diego State University

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Abstract

This study tested the hypothesis that students with a field-independent cognitive style would learn more about numeration systems if they had minimum guidance and maximum opportunity for discovery through the use of manipulative materials. Field-dependent students were expected to perform better with maximum guidance and a symbolic treatment. Data were gathered on 46 prospective elementary school teachers who had been randomly assigned to two treatment groups. Multiple regression analysis revealed a significant disordinal interaction supporting the hypothesis for one of the two achievement measures.

Relating Field Independence and a Discovery Approach to Learning Mathematics: A Trait-treatment Interaction Study

The search for interactions between individual difference variables and instructional treatments in mathematics is generally viewed as an outgrowth of the work of Cronbach (1957). These interactions are referred to as aptitude-treatment interactions (ATI) or, more recently (Berliner & Cahen, 1973), as trait-treatment interactions (TTI). For recent reviews, see Cronbach (1975), Hunt (1975), and Tobias (1976).

The lack of significant results in early TTI research in mathematics education may have been due to the choice of aptitude variables. Behr and Eastman (1975) have suggested that a whole new theory of mathematical aptitudes might be necessary. Another approach would be to take a broader view of individual difference variables and include traits such as cognitive styles. Witkin's notion of field-dependence-independence (Witkin, Moore, Goodenough, & Cox, in press) is a dimension of cognitive style that seems particularly promising for TTI research in mathematics. Witkin views cognitive style as an individual's characteristic mode of functioning, displayed consistently in both perceptual and intellectual activities. Students are said to be field independent if they have the ability to separate part of a field from the whole; they are said to be field dependent if they do not do well on such tasks. While field-dependence-independence is assessed through a perceptual task, it is also related to some types of academic performance. For example, students who are field independent are more able to work inde-

pendently than field-dependent students, who seem to do best when they have more direction from the teacher or the text.

Certain dimensions of discovery learning in mathematics seem to be related to the differences in cognitive style between field-independent and field-dependent students. Carpenter, McLeod, and Skvarcius (Note 1) reported a significant disordinal interaction between field-dependence-independence and the level of guidance on two of four dependent variables ($p < .05$) in a study using college mathematics students. As predicted by Witkin's theory, in that study field-independent students did significantly better under conditions of minimum guidance, while field-dependent students seemed to learn more when they received maximum guidance.

Insert Figure 1 about here

Figure 1 presents the regression lines for each of the four treatment groups in that study. The treatments were based on two levels of guidance crossed with two levels of abstraction: minimum guidance with manipulative materials (Min-M), maximum guidance with manipulatives (Max-M), minimum guidance with only a symbolic presentation (Min-S), and maximum guidance with only a symbolic presentation (Max-S). The Min-M regression line had the greatest slope, while the Max-S regression line was negative, a surprising result since field independence generally has a positive correlation with

performance in mathematics.

The interesting results shown in Figure 1 prompted the present study. The purpose of this study was to investigate further the interaction between field-dependence-independence and treatments differing in level of guidance and level of abstraction. Specifically, it was hypothesized that there would be a significant interaction between field-dependence-independence and the Min-M and Max-S treatments, with field-independent students doing better in the Min-M treatment and field-dependent students excelling in the Max-S treatment. The Min-M treatment used low guidance and a concrete level of abstraction; both of these characteristics can be viewed as at the "discovery" end of the spectrum for these dimensions of instruction (Shulman, 1970). The Max-S treatment, on the other hand, was similar to the more "expository" approach taken by most textbooks.

Method

Subjects

Students from two sections of a mathematics course for prospective elementary school teachers participated in this study. The 55 students were randomly assigned to treatment groups within each section. Students who were absent on one or more days were dropped from the study, leaving 46 students for which complete data were obtained. Of these 46 students, the Min-M group contained 21 and the Max-S group 25.

Materials

The treatments and tests used in this investigation were based on

those developed for the earlier study by Carpenter et al. (Note 1). The topic presented was addition and subtraction in bases other than ten, a standard part of the course. The printed materials varied in level of guidance (minimal or maximal) and level of abstraction (concrete or symbolic): the Min-M treatment having minimal guidance and a concrete level of abstraction and the Max-S treatment having maximal guidance and a symbolic level of abstraction. Multi-base arithmetic blocks were used with the Min-M printed treatment materials. Both treatments covered the same content, used the same problems presented in the same order, and provided about the same amount of practice. All problems and examples involved bases four and five.

All subjects were given a pretest, two posttests, and a test designed to measure field-dependence-independence. The pretest, which was used as a covariate, measured knowledge of prerequisite concepts involving representing numbers in bases other than ten, changing number bases, and applications of these concepts. Students were given up to 15 minutes for the pretest.

Two ten-minute posttests were given. In one (QS), all problems were presented symbolically and no blocks were available. In the other (QM), some of the problems were presented as pictures of blocks and students were encouraged to use the multibase blocks during the test. The use of posttests that differ in level of abstraction is a strategy recommended by Kieren (1969) for studies related to this dimension of discovery learning.

The measure of field-dependence-independence chosen for the study was Hidden Figures 2, Form 271, a version of the Hidden Figures Test (HFT) that was adapted from the original of the Educational Testing Service for use in the National Longitudinal Study of Mathematical Abilities (NLSMA). For a

discussion of this test and its characteristics, see the appropriate NLSMA reports (Romberg & Wilson, 1969, p. 178; Wilson, Cahen, & Begle, 1968, p. 138). Since the NLSMA data indicated that the test statistics were influenced by a speed factor, the HFT was changed again for this study by allowing the students 15 rather than 10 minutes for the test.

Procedures

The students were told in advance that the class would be working on a series of special assignments that involved some work in the mathematics laboratory. They were also informed that an extra instructor would be available so the class could be split into two smaller groups. At the conclusion of the study, the different treatments were described in more detail, and those students who had not had a chance to use the manipulative materials received additional instruction.

An instructor from one of the two classes and the course supervisor conducted the treatments. They were randomly assigned to the Max-S treatment group in one class and to the Min-M treatment group in the other class. Thus each instructor taught each treatment once. Within each class, students were randomly assigned to treatment groups within levels of HFT scores.

One class met three times a week for 50-minute periods. In this class the pretest was administered on the first day, and treatments conducted during the second day. In the other class, which met twice a week for 75-minute periods, the pretest was given just prior to the treatments. Treatments were conducted in different rooms, the Max-S group staying in the regular classroom and the Min-M group going to the mathematics laboratory.

In both classes, the posttests were given during the next class meeting after the treatments (two days later).

Each student worked individually on a packet of printed materials designed for his/her treatment group (Min-M or Max-S). Students were given 50 minutes to complete the treatment. For the Min-M group, instruction began with an introduction to the manipulative materials, multibase arithmetic blocks. First, the students were shown how to represent numbers in base five using the blocks. Then, without further instruction, students began working on the problems. If a student asked a question, the instructor encouraged him to use the blocks to discover the answer for himself.

The Max-S group did not see the blocks during instruction. Instead, the instructor presented to the students solutions of sample problems given in the Max-S materials. The instructor's verbal presentation followed the printed materials closely. Students then worked the problems, using addition tables to complete the computations. If a student asked a question, the instructor answered it directly and completely.

Subjects in the Max-S group were shown how to use the blocks to represent numerals in bases other than ten just before taking the QM posttest. They were given a sample problem in base six in which they were asked to represent a picture of some blocks as a numeral. Students were able to do this and appeared to understand how to use the blocks.

Since the problems were in base six on the QM posttest and in base three on the QS posttest it would be inappropriate to compare group results across the two tests. However, the two tests were similar in structure. Each

contained four problems in addition and subtraction similar to those used in the treatments, as well as transfer problems on multiplication and division, topics that were not part of the instruction.

The pretest and posttests were graded by the two instructors conducting the study. No partial credit was allowed for incomplete answers.

Results

The results were analyzed using multiple regression techniques as presented by Kerlinger and Pedhazur (1973). Each of the two dependent variables, the symbolic test (QS) and the manipulative materials test (QM), was analyzed separately. First, the results for a given test were checked for an interaction between the pretest and the treatments. Since there were no such interactions, it was appropriate to use the pretest as a covariate. Thus, the model for the regression analysis included vectors for the pretest scores, the HFT scores, the treatments, and the treatment-by-HFT interaction.

On the QS posttest, there was a significant interaction between the HFT scores and the treatments. For this test, about 47% of the variance was accounted for by the predictors. The change in R^2 that occurred from dropping the interaction vector was .059, yielding $F(1,41) = 4.54$, $p < .05$. Figure 2 shows the disordinal nature of the interaction, and its direction is as predicted.

Insert Figure 2 about here

Since the interaction was significant, the Johnson-Neyman technique (Kerlinger & Pedhazur, 1973, p. 256) was applied to the QS posttest using only the HFT scores as predictors. The region of HFT scores where the differences between treatments were significant (alpha level of .05) contained about 30% of the students. Students did significantly better in the Max-S treatment than the Min-M treatment if their HFT scores were four or less. No student scored above the upper limit of the Johnson-Neyman region of nonsignificance.

For the QM posttest, there was no significant interaction between HFT scores and treatments. The data were analyzed further to see if there were any differences between the treatment groups; none were found.

Table 1 includes the basic descriptive data for each test by treatment group. The correlation matrix and the KR-20 reliability coefficients are presented in Tables 2 and 3, respectively. Table 4 displays the regression equation data for each group.

Insert Tables 1-4 about here

Discussion

This study tested the hypothesis that field-dependence-independence would interact with treatments that differed in two dimensions of discovery approaches to mathematics, level of guidance and level of abstraction. This

hypothesis was confirmed on the QS posttest, one of two dependent variables. This result helps to confirm other interactions found in a related research project (Carpenter et al., Note 1). This confirmation of an earlier result is particularly important to TTI research in mathematics education, an area where there has been little success in finding interactions and where replications have been rare, indeed (Behr & Eastman, 1975).

It should also be noted that this interaction occurred in a rather small study (46 subjects) using materials and procedures that, while carefully controlled, were not that far removed from common classroom practice. The Min-M treatment, for example, has parallels in any school that has a mathematics laboratory where students work independently with minimal guidance from the teacher. The Max-S treatment, on the other hand, uses materials that are similar to many standard mathematics texts.

There were no significant interactions for the other dependent variable, the QM posttest. While the graphs of the regression lines are in the direction predicted by the theory, the proportion of the variance that was accounted for by the interaction was small.

Other dimensions of discovery approaches to mathematics, such as the sequence of instruction and the use of small groups, may also be related to field-dependence-independence. The use of inductive and deductive sequences of instruction has been investigated by McLeod and Briggs (Note 2). They found an interaction between field-dependence-independence and sequence of instruction on only one of four dependent variables, which suggests that sequence of instruction by itself is not a promising treatment variable.

It seems more likely that varying the level of guidance along with the sequence of instruction (as described by Shulman, 1970, p. 67) would be a more promising route for future research on the relationship of field-dependence-independence to mathematics instruction.

Reference Notes

1. Carpenter, T. P., McLeod, D. B., & Skvarcius, R. Cognitive style and mathematics learning: The interaction of field independence and instructional treatment in numeration systems. Paper presented at the Annual Meeting of the National Council of Teachers of Mathematics, Atlanta, April 1976.

2. McLeod, D. B., & Briggs, J. T. The interaction of field independence and general reasoning ability with inductive instruction in mathematics. Paper presented at the Annual Meeting of the National Council of Teachers of Mathematics, Cincinnati, April 1977.

References

Behr, M. J., & Eastman, P. M. Interactions between structure-of-intellect factors and two methods of presenting concepts of modulus seven arithmetic - a follow-up and refinement study. Journal for Research in Mathematics Education, 1975 6, 150-157.

Berliner, D. C., & Cahen, L. S. Trait-treatment interaction and learning. In F. N. Kerlinger (Ed.), Review of research in education. Itasca, Illinois: Peacock, 1973.

Cronbach, L. J. The two disciplines of scientific psychology. American Psychologist, 1957, 12, 671-684.

Cronbach, L. J. Beyond the two disciplines of scientific psychology. American Psychologist, 1975, 30, 116-127.

Hunt, D. E. Person-environment interaction: A challenge found wanting before it was tried. Review of Educational Research, 1975, 45, 209-230.

Kerlinger, F. N., & Pedhazur, E. J. Multiple regression in behavioral research. New York: Holt, Rinehart, & Winston, 1973.

Kieren, T. E. Activity learning. Review of Educational Research, 1969, 39, 509-522.

Romberg, T. A., & Wilson, J. W. The development of tests. NLSMA Reports, No. 7. Stanford, California: School Mathematics Study Group, 1969.

Shulman, L. S. Psychology and mathematics education. In E. G. Begle (Ed.), Mathematics education. The Sixty-ninth Yearbook of the National Society for the Study of Education, Part 1. Chicago: University of Chicago Press, 1970.

Tobias, S. Achievement treatment interactions. Review of Educational Research, 1976, 46, 61-74.

Wilson, J. W., Cahen, L. S., & Begle, E. G. (Eds.). Description and statistical properties of Z-population scales. NLSMA Reports, No. 6. Stanford, California: School Mathematics Study Group, 1968.

Witkin, H. A., Moore, C. A., Goodenough, D. R., & Cox, P. W. Field-dependent and field-independent cognitive styles and their educational implications. Review of Education Research, in press.

Table 1

Means and Standard Deviations

of All Tests for Each Treatment Group

			Treatment Groups			
	Maximum Possible		Min-M		Max-S	
Test	Score	Range	Mean	SD	Mean	SD
HFT	16	1-16	7.1	3.4	6.2	3.3
Pretest	13	0-12	4.8	3.5	6.1	3.9
Posttest						
QS	6	0-6	2.8	2.2	3.7	2.0
QM	6	0-6	3.0	1.6	2.9	1.9

Table 2

Correlation Matrix for All Tests

Test	Correlation			
	1	2	3	4
1. HFT	1.00	.41	.40	.21
2. Pretest		1.00	.59	.46
3. QS Posttest			1.00	.50
4. QM Posttest				1.00

Table 3

Reliability Coefficients for All Tests

	Treatment Groups		
Test	Min-M	Max-S	Total
HFT	.76	.76	.76
Pretest	.85	.89	.86
Posttest			
QS	.84	.84	.84
QM	.69	.74	.70

Table 4

Regression of Posttests on Pretest and Hidden Figures Test for Each Treatment Group

Posttest	Group	Intercept	Pretest	HFT	R^2	F
QS	Min-M	-1.07	.38	.28	.70	20.92[a]
	Max-S	2.10	.22	.04	.22	3.16[b]
QM	Min-M	1.43	.27	.04	.36	5.00[a]
	Max-S	1.84	.21	-.04	.17	2.21[b]

[a]Degrees of freedom are (2,18); $p = .05$ for $F = 3.55$.

[b]Degrees of freedom are (2,22); $p = .05$ for $F = 3.44$.

Figure 1. Regression lines for all four treatment groups on QM posttest. Adapted from Carpenter, et al., Note 1.

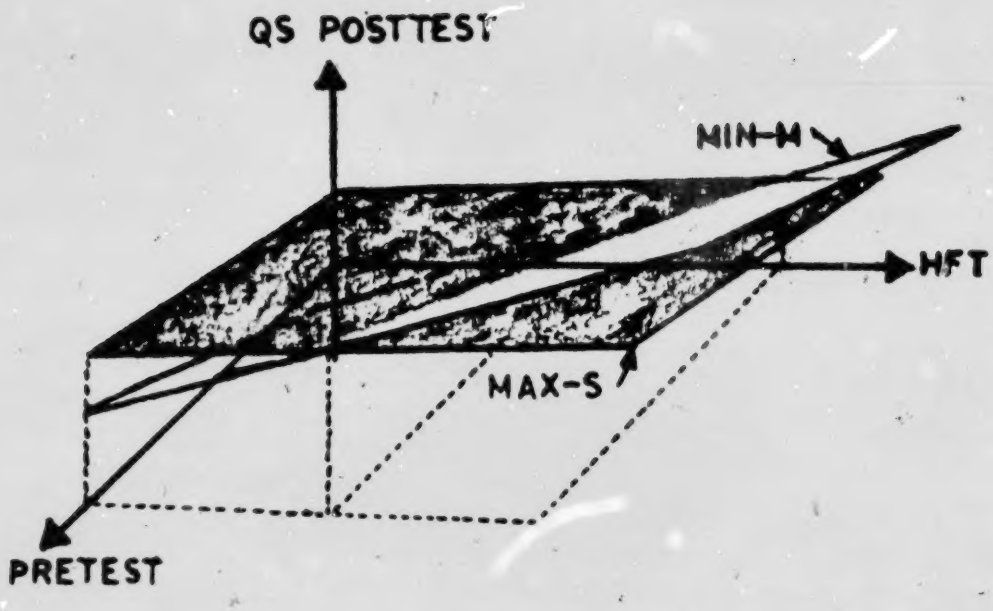

Figure 2. Regression planes for the Min-M and Max-S treatments.